ABSTRACT

APPLICATION OF TISSERAND'S CRITERION TO THE DESIGN OF GRAVITY ASSIST TRAJECTORIES

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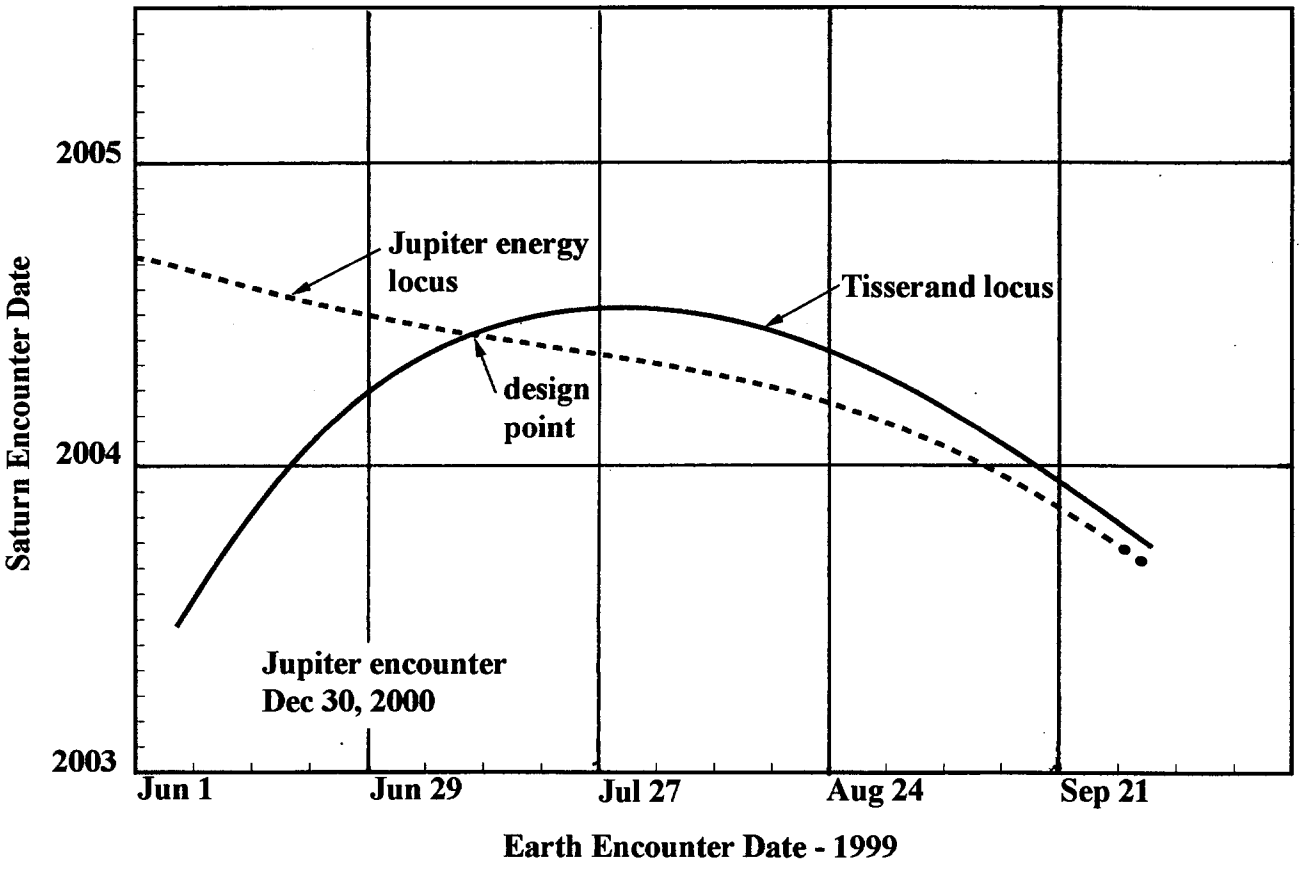
The design of interplanetary trajectories involves finding an orbit that will transfer a spacecraft from the vicinity of one planet to the vicinity of another planet. The accessibility of a target planet, particularly those beyond the orbit of Jupiter, depends on finding a transfer orbit with energy relative to the initial starting point, normally the Earth, within the capability of the launch vehicle. The use of gravity assist to increase the transfer orbit energy has opened up the exploration of planets that otherwise would not be accessible with current launch vehicle capability. Gravity assist involves finding an intermediate planet on the way to the target planet that provides an acceleration of the spacecraft from its gravity to increase the orbit energy.

A problem in the design of gravity assist trajectories is finding the encounter times, or time of flyby, of the launch planet, intermediate planet and target planet. Once these times are determined, it is a relatively simple procedure to use Lambert's theorem and numerical integration to complete the detailed design. In this paper, a procedure is described for finding these encounter times using Lambert's theorem and Tisserand's criterion to identify pairs of transfer orbits between the launch planet and intermediate planet and between the intermediate planet and target planet.

Francois Felix Tisserand was a nineteenth century astronomer who discovered a unique application of Jacobi's integral to identify comets. In the restricted three body problem, a certain function of the orbit elements before and after a planetary encounter is conserved. If this function is computed for two comet observations on different orbits and the results are the same, one may conclude that the observations are of the same comet and the comet has encountered a planet between the observations. This may be confirmed by propagating the orbits forward and backward in time to see if they encountered a planet at the same time.

In the application of Tisserand's criterion to gravity assist trajectory design, the procedure is reversed. Transfer trajectories from the launch planet to the intermediate planet and from the intermediate planet to the target planet are computed using Lambert's theorem. These trajectories are matched based on Tisserand's criteria and the incoming and outgoing energies with respect to the intermediate planet. If both the energy and Tisserand's criterion are satisfied, a candidate set of encounter times has been found for further analysis.


2005
2004
2003
Saturn Encounter Date
Jupiter energy locus
Tisserand locus
design point
Jupiter encounter Dec 30, 2000
Jun 1
Jun 29
Jul 27
Aug 24
Sep 21
Earth Encounter Date - 1999